Visual Phase Unwrapping (Version: 1.0) User Guide

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- Prof. Hua Wang — Department of Surveying Engineering, Guangdong University of Technology.
- Prof. Huayang Dai — College of Geoscience and Surveying Engineering, China University of Mining & Technology, Beijing.

Abbreviations and Symbols

Abbreviations

The following abbreviations will be used frequently in this guide:

- VPU — Visual Phase Unwrapping
- GUI — Graphic User Interface
- InSAR — Interferometric Synthetic Aperture Radar
- MCF — Minimum Cost Flow

Symbols

This guide uses the following symbols and conventions:

Caution

- Caution

  This indicates important notices and restrictions for using this software.

Note

- Note

  This indicates supplementary explanations and useful tips about software operations.

Reference

- Reference

  This indicates page(s) relevant to a particular function. “P. xx” is used to refer you to pages in this guide.

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I. INTRODUCTION

1.1. Visual Phase Unwrapping (VPU) Overview

Visual Phase Unwrapping (VPU) is a cross-platform C++ application designed for interferometric synthetic aperture radar (InSAR) applications. It is developed by Dr. Kui Zhang and available for Windows and Linux systems.

The design and development of VPU are based on the developer's long-term InSAR data processing experience. With the use of VPU, users can easily manipulate an InSAR phase unwrapping process. VPU can be also used as a good image viewer for representing InSAR data.

1.2. Notable features of VPU

- **Cross-platform GUI support:** The GUI of VPU is carefully implemented by using wxWidgets [1]. Users can use VPU on both Windows and Linux.
- **Synchronized input/output data views:** In VPU, the input wrapped data and the output unwrapped data are placed in two scrolled views, respectively. If the origin or the size of one view is changed, the other will be "synchronized" with it immediately. This feature may help users to better observe and evaluate a phase unwrapping result.
- **Powerful mask functions:** VPU allows users to straightforwardly create phase unwrapping masks on both wrapped data view and unwrapped data view with the use of supported shapes. Vectorized mask information can be rapidly stored and loaded.
- **Different integration strategy available:** The introduction of masks may lead to input data being separated into isolated areas. VPU will define an isolated phase unwrapping problem for each area. There are two integration strategies available in VPU. The first one is only carried out on the largest sub-area. The second one will integrate all isolated areas. In this case, users can obtain an independent phase unwrapping result on each sub-area.
- **Various built-in color maps support:** VPU provides several color

maps for InSAR data display, which enables input/output data to be illustrated better in different situations.

- **Big endian data support:** Users can load, process and store both little endian and big endian data in VPU.

Note

- The kernel phase unwrapping algorithm currently used in VPU is an extended version of the minimum cost flow (MCF) algorithm proposed by M. Costantini. For more detail about the MCF algorithm, users can refer to the articles [2] and [3].
- The MCF solver follows the implementation in LEMON [4].

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III. GETTING STARTED

3.1. Installing VPU

3.1.1. Supported operating systems

- Microsoft® Windows® XP Professional Edition (64-bit)
- Windows Vista® Home Basic, Home Premium, Business, Ultimate, or Enterprise (64-bit)
- Windows 7/8(64-bit)
- Common used 64-bit Linux systems (with GTK; glibc>= 2.15). VPU has been successfully tested on:
  - ✧ Ubuntu 14.04
  - ✧ Debian 7.7
  - ✧ OpenSUSE 13.2
  - ✧ Fedora 22
  - ✧ CentOS 7.0

Note

- As mentioned previously, the key phase unwrapping algorithm of VPU is based on the MCF method. When input data is relatively large, a great deal of memory is required to construct the corresponding phase unwrapping network. Therefore, only the 64-bit version of VPU is provided, although it is very easy to generate a 32-bit version using VPU's source code.

3.1.2. Recommended minimum hardware for better performance

- Intel® Core™ i5 or faster processors
- 8GB RAM or greater
- 1024×768 screen resolution or higher

3.1.3. Installing VPU on Windows

It is very straightforward to install VPU on Windows. Users only need to download the installation package "vpu_win64_*_setup.exe" from VPU's home website and execute it for a setup process. After the installation, users can directly click the file "VPU.exe" to open the software.

3.1.4. Installing VPU on Linux

Please install VPU on Linux as the following steps (take Debian for example):

1) Download the software package "vpu_linux64_*_setup.tar.gz" from VPU's home website and decompress it to a specific folder (e.g. /home/kui/VPU).

2) Using the "su" command to run as the root user:

```
kui@debian:~/VPU$ su
```

3) Execute the installation process:

```
root@debian: /home/kui/VPU# sh VPU_linux64_v1.0_setup.bin
```

4) Switch to the normal user:

```
root@debian: /home/kui/VPU# exit
```

5) Open the software:

```
kui@debian:~/VPU$ VPU
```

Caution

The glibc version of Linux operating systems must be greater than or equal to 2.15. Otherwise, VPU will fail to start and users may see an error as follows:

/lib/x86_64-linux-gnu/libc.so.6: version `GLIBC_2.15' not found

To fix this error, users can upgrade the glibc as follows (take Debian for example):

1) Add the following line to the file /etc/apt/sources.list:

   deb http://ftp.debian.org/debian sid main

2) Using the "su" command to run as the root user:

```
kui@debian:~/ $ su
```

3) Update your package database:

```
root@debian: /home/kui/# apt-get update
```

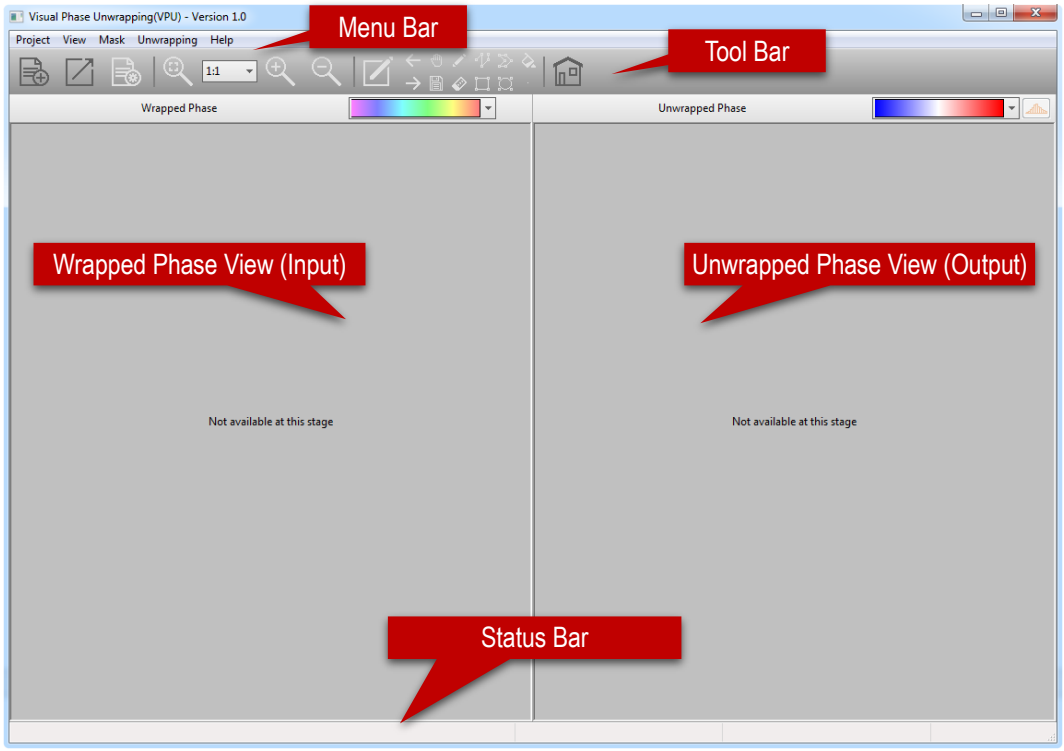
4) Install the eglibc package:

```
root@debian: /home/kui/# apt-get -t sid install libc6-amd64 libc6-dev libc6-dbg
```

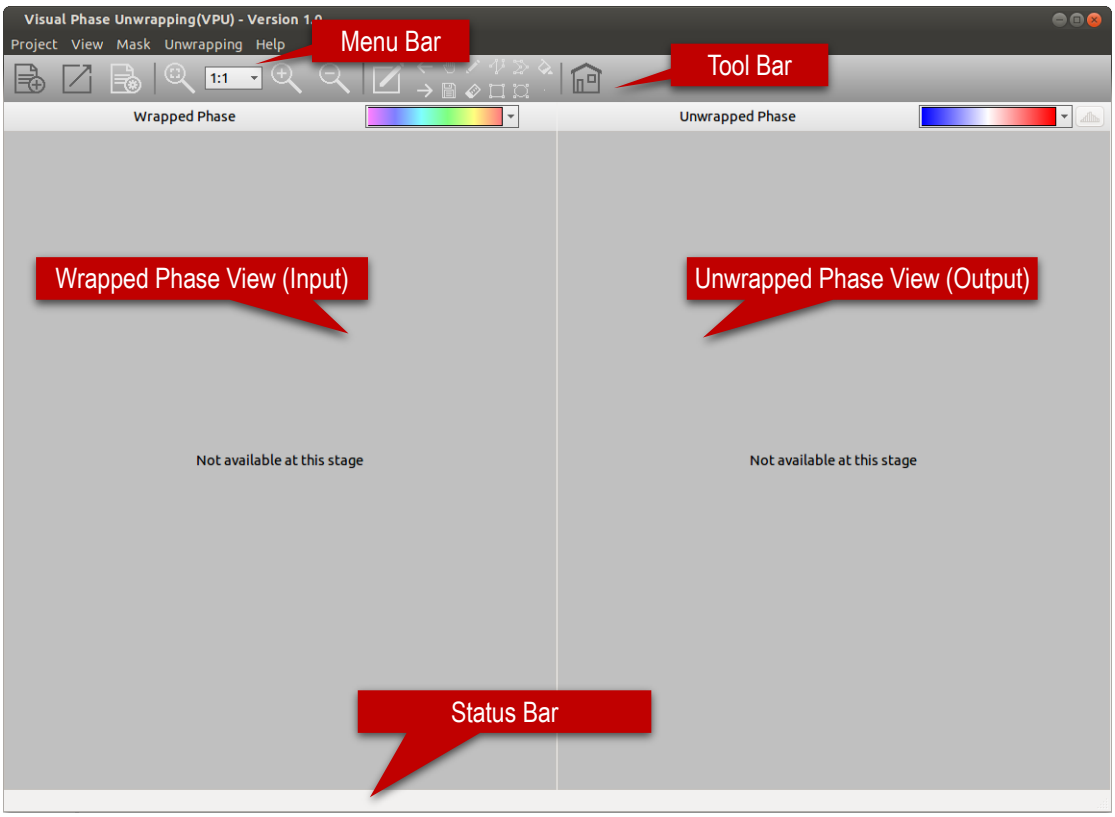
5) **IMPORTANT**: After libc6 has been updated, restart computer, and you should comment out or remove the sid source you just added (deb http://ftp.debian.org/debian sid main).

3.2. GUI overview

3.2.1. Main interface



The main interface of VPU (On Windows7)



The main interface of VPU (On Linux-Ubuntu)

After you open VPU, the main interface of the software will be popped up, as shown by the above figures. VPU likes most document viewing applications. There's a menu and toolbars along the top, a status bar along the bottom, and two views to display input/output data and masks.

- **Menu Bar:** Gives you access to all the commands in VPU.
- **Tool Bar:** Gives you quick access to the tools you will use regularly.
- **Status Bar:** Displays information about the menu bar or tool bar items.
- **Wrapped Phase View (Input):** Displays the input wrapped phase and corresponding masks.
- **Unwrapped Phase View (Output):** Displays the resulting unwrapped phase and corresponding masks.

3.2.2. Looking at the key operations

To running with VPU quickly, it's useful to understand some of key operations you'll need to do the basics — like creating a project, enabling mask editing and executing phase unwrapping.

Menu bar Command	Tool bar Button	Operation description
Project->New		Create a new project for phase unwrapping
Project->Open		Open an old phase unwrapping project
Project->Parameters		Edit the parameters of the current project
View->Fit		Fit data to two views
View->Zoom In		Zoom in two views
View->Zoom Out		Zoom out two views
Mask->Edit		Enable VPU to edit mask areas for phase unwrapping
Unwrapping->Execute	(none)	Unwrap the input data using the minimum cost flow method
Help->VPU Home		Go to VPU home website to check software update
Help->VPU Guide	(none)	Learn how to use Visual Phase Unwrapping
Help->About VPU	(none)	Display the information about VPU and the software license

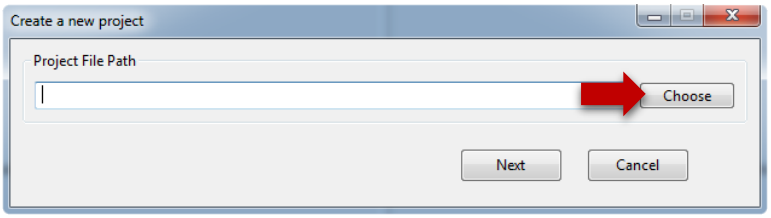
IV. Basic Phase Unwrapping Procedure

VPU makes phase unwrapping procedures as simple and streamlined as possible. For a basic phase unwrapping procedure, there is nothing to learn, and nothing to remember.

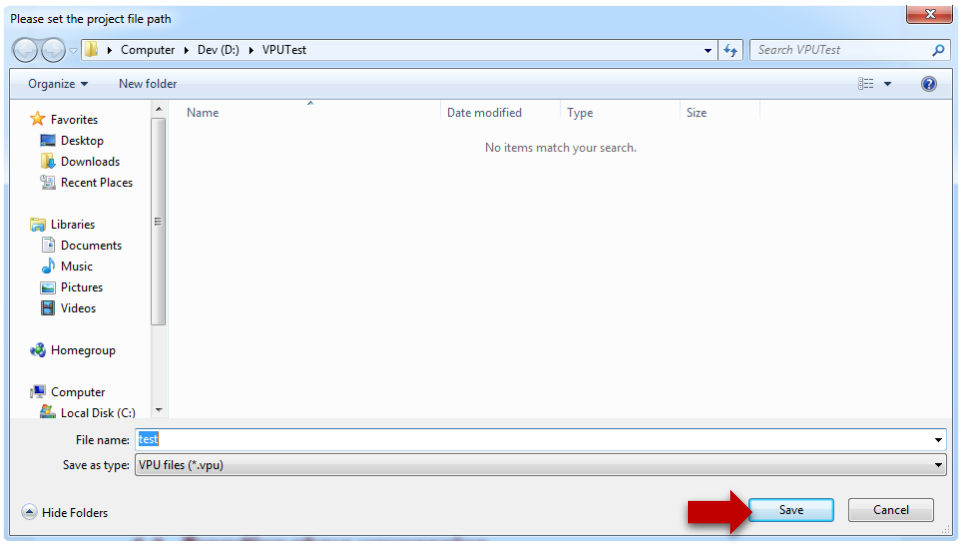
4.1. Creating a phase unwrapping project

Like most GUI applications, a phase unwrapping project has to be created at beginning in VPU. To do this,

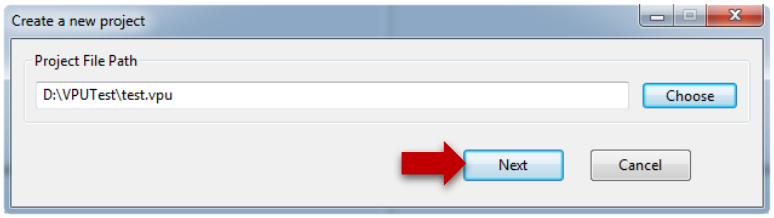
1) Choose "Project->New" from the menu bar or click the corresponding button on the tool bar. Then, a dialog entitled "Create a new project" will be popped up as follows.



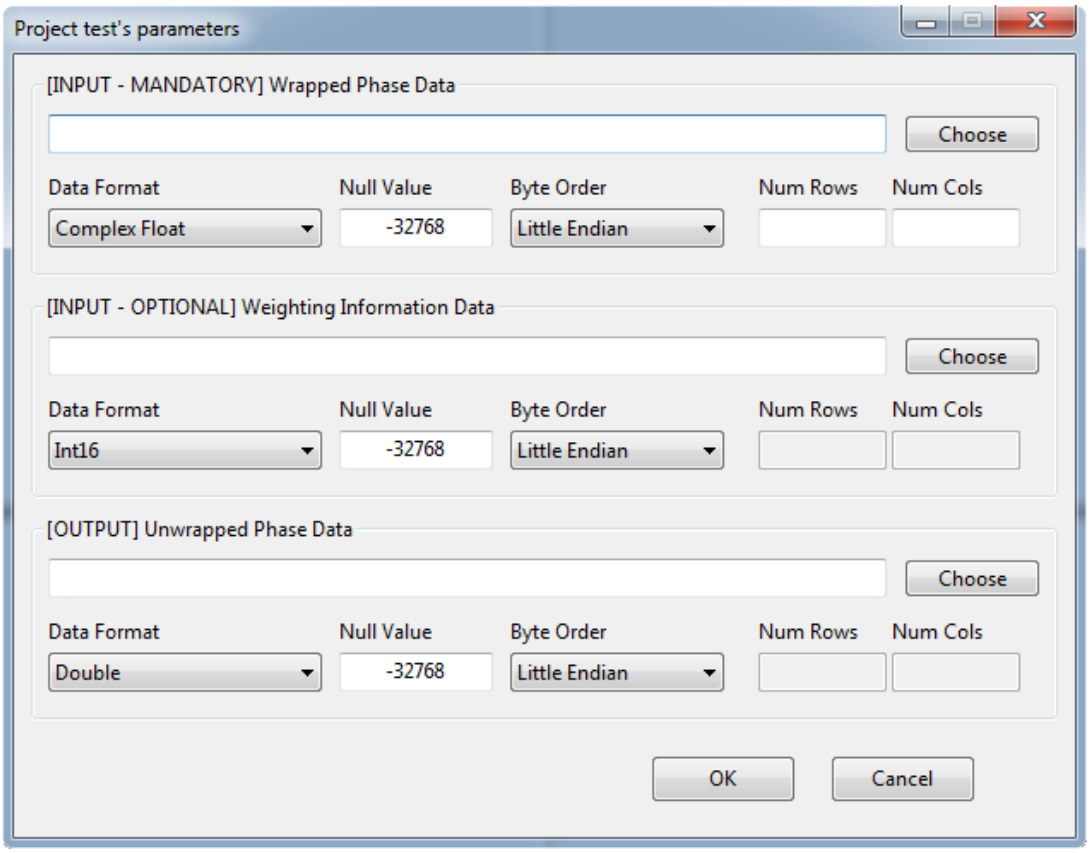
2) Click the button "Choose". Set the project file via the OS built-in file open dialog as follows.



3) Click the button "Save". Then, click the button "Next" on the dialog "Create a new project".



4) Subsequently, VPU will ask users to set corresponding parameters for the project via a dialog listed below.



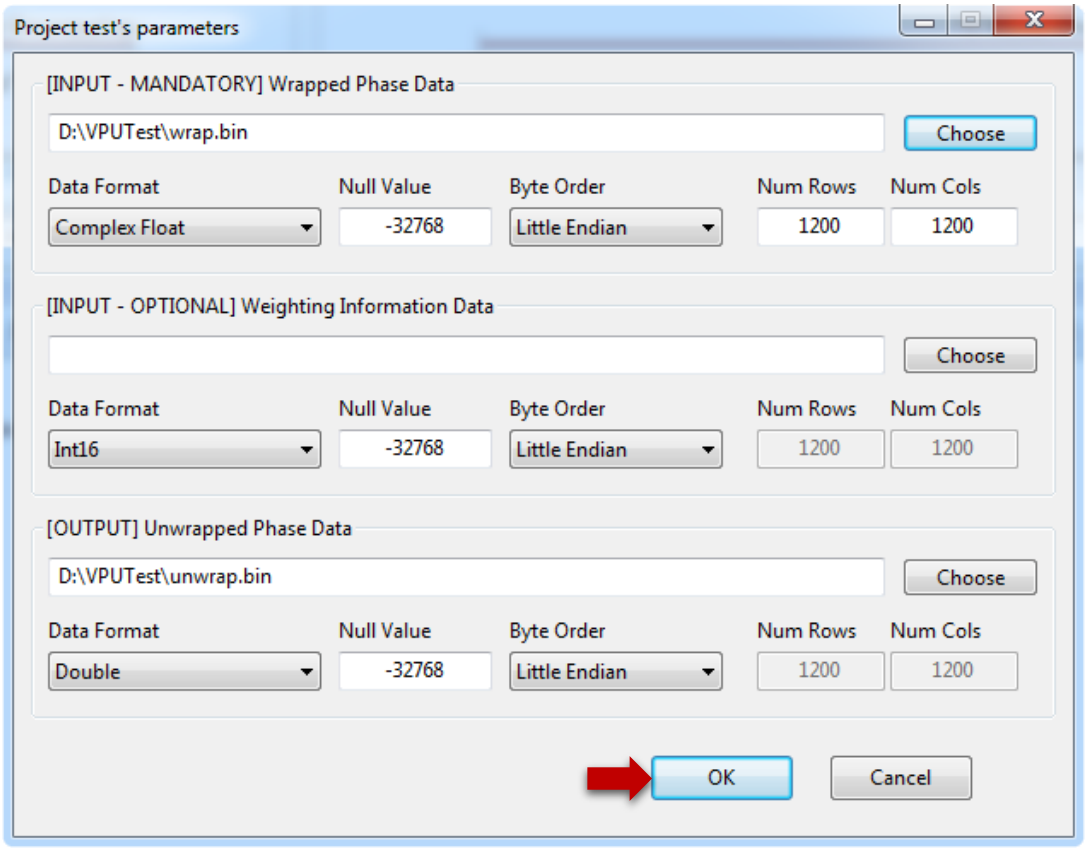
The required parameters are:

- **The path of the wrapped phase data:** This is a **mandatory** input parameter. It can be set by clicking the corresponding button "Choose".
- **The data format of the wrapped phase data:** Users can choose it by clicking the corresponding data format list box (Supported format: Complex Float – 8 Bytes, Complex Double – 16 Bytes).
- **The dimension of the input/output data:** Users can set it by filling the two enabled edit controls under the text "Num Rows" and "Num Cols".
- **The path of the weighting information data:** This is an **optional** input parameter. It can be set by clicking the corresponding button "Choose".
- **The data format of the weighting information data:** Users can

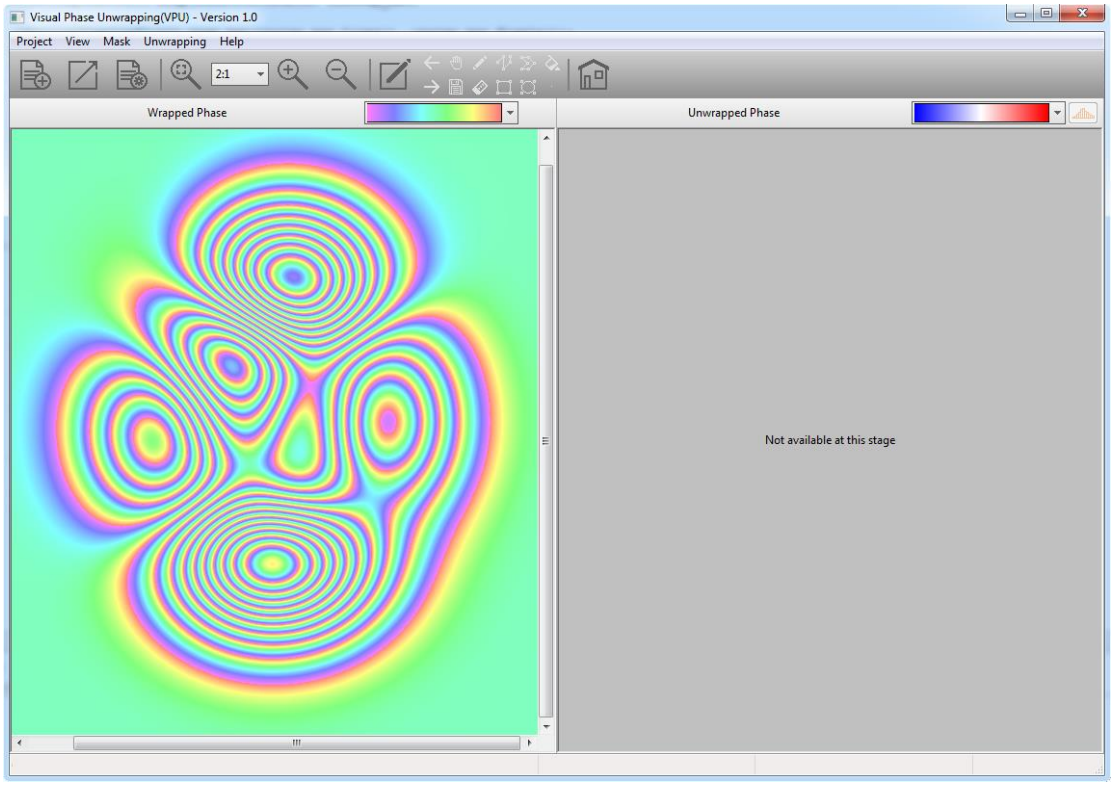
choose it by clicking the corresponding data format list box (Supported format: Float – 4 Bytes, Double – 8 Bytes, Int16 – 2 Bytes, Int32 – 4 Bytes).

- **The path of the unwrapped phase data:** It can be set by clicking the corresponding button "Choose".
- **The data format of the unwrapped phase data:** Users can choose it by clicking the corresponding data format list box (Supported format: Double – 8 Bytes, Float – 4 Bytes).
- **Null Value for each data:** The default value is -32768 for each data. Users can directly change it in the corresponding edit control.
- **The byte order of each data:** The default byte order for storing or loading each data is little endian. Users can change it to big endian by clicking the corresponding byte order list box.

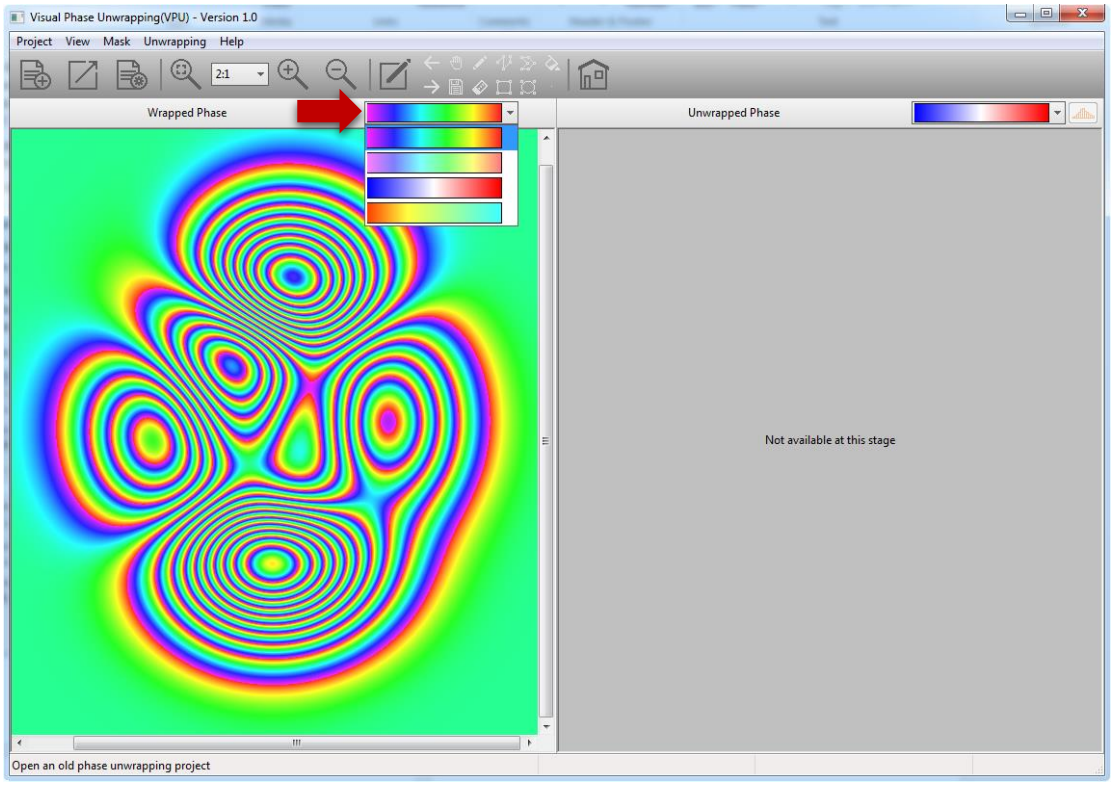
5) Click the button "OK". The creation of the project is completed.



6) Finally, the input wrapped phase and the output unwrapped phase (if exists) will be loaded and displayed on the corresponding views.



There are four kinds of color maps available for displaying input/output data. In order to display mask areas more clearly, the default color map for the wrapped phase is light rainbow. Users can change it by directly clicking the color bar list box above each view.

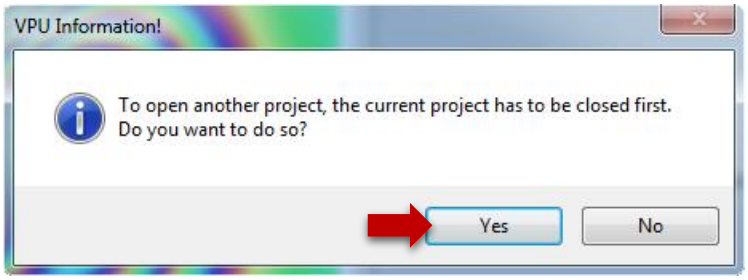


4.2. Opening an existed project

VPU allows users to load an existed project into the current workspace. To do this, just choose “Project->Open” from the menu bar or click the corresponding button on the tool bar.

Note

To open an exited project, the project which has been already opened in the workspace has to be closed. A confirmation dialog will be popped up. Users have to click the button “Yes” to confirm this operation.



4.3. Edit project parameters

To change current project’s parameters, users can choose “Project->Parameters” from the menu bar or click the corresponding button on the tool bar. After this operation, the parameter dialog will be popped up.

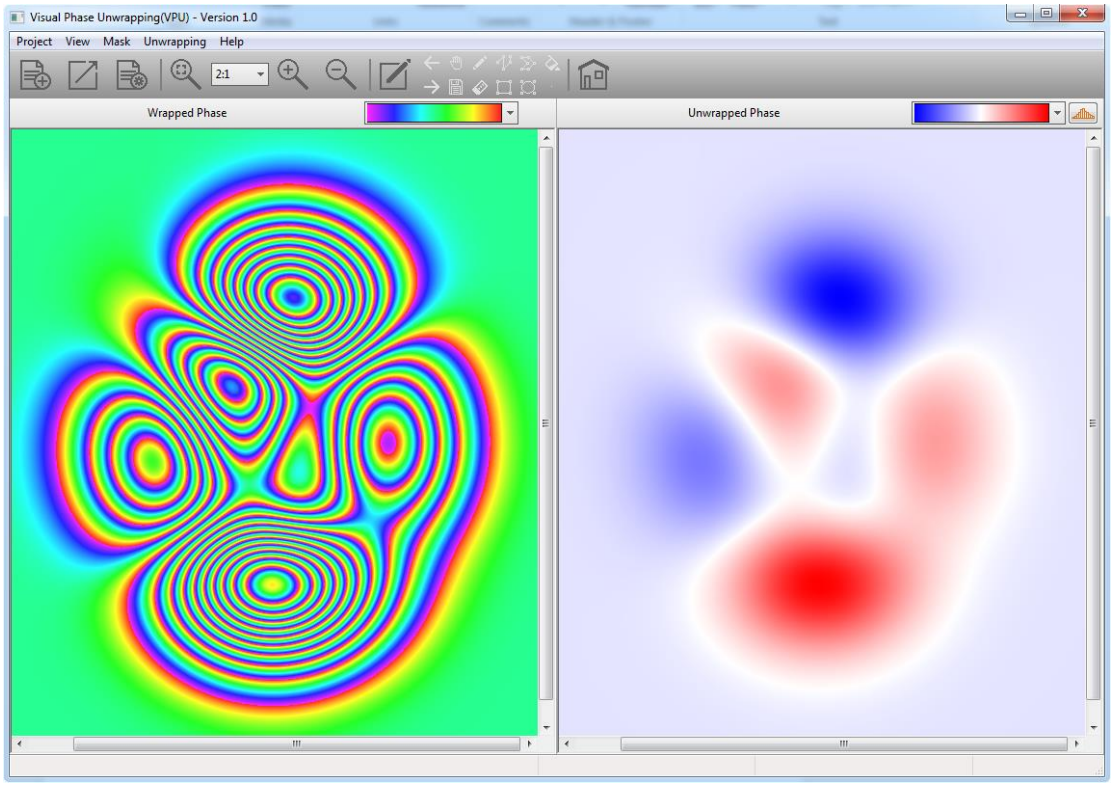
Reference

For more detail about dealing with the parameter dialog, please refer to *Section 4.1. Creating a phase unwrapping project* (P.17 — P.20).

4.4. Executing phase unwrapping

After the creation of a project, a phase unwrapping process can be directly carried out by choosing Unwrapping->Execute from the menu bar. Next, VPU will ask users to select the integration method for the unwrapping process. When VPU completes this process, the resulting

unwrapped phase will be displayed on the corresponding view.

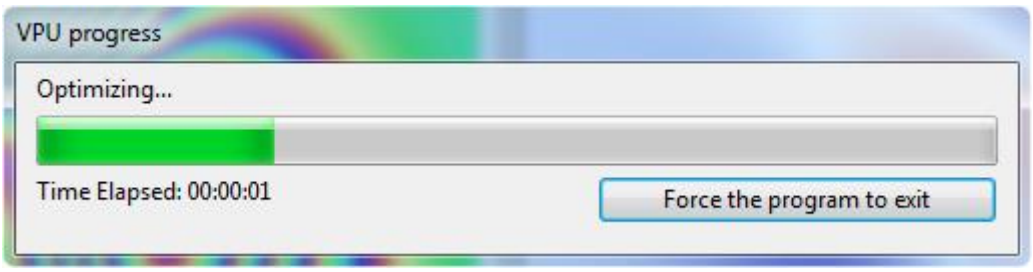


Reference

For more detail about integration method selection, please refer to *Section 5.2. Integration method selection* (P.29 — P.30).

4.5. About the progress dialog

During the execution of the phase unwrapping algorithm, a progress dialog will be popped up, as shown below.

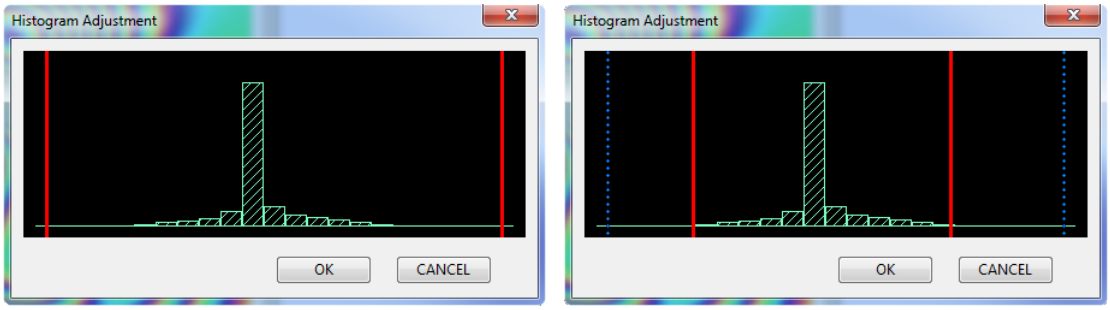


MCF method has non-linear time complexity. When the input data contains a large number of residues, a phase unwrapping process may not be completed within a reasonable time. There is a button named "Force the program to exit" on the process dialog. Users can stop a

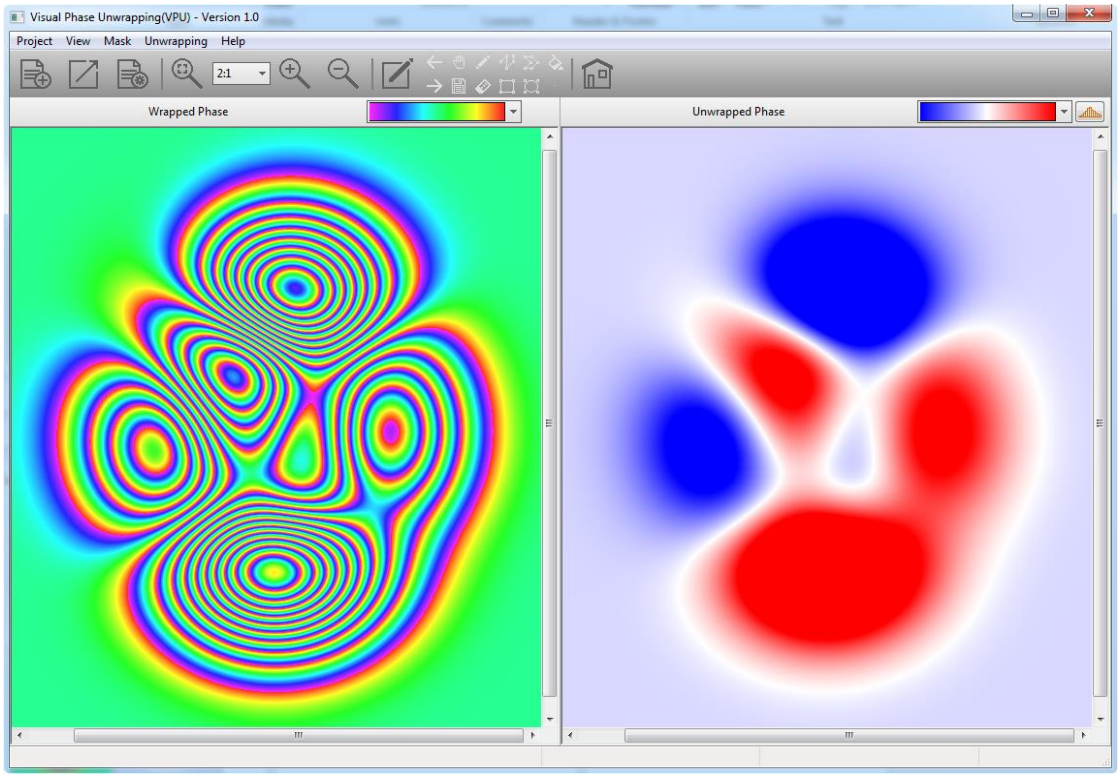
phase unwrapping process by clicking this button.

4.6. Histogram adjustment

To better observe and evaluate a phase unwrapping result, VPU allows users to adjust the histogram of the output unwrapped phase. To do this, please click the button above the unwrapped phase view. After this button being clicked, the histogram of the output unwrapped phase will be shown in a dialog, as shown below. Users can adjust it by directly dragging the two red lines shown on this window.

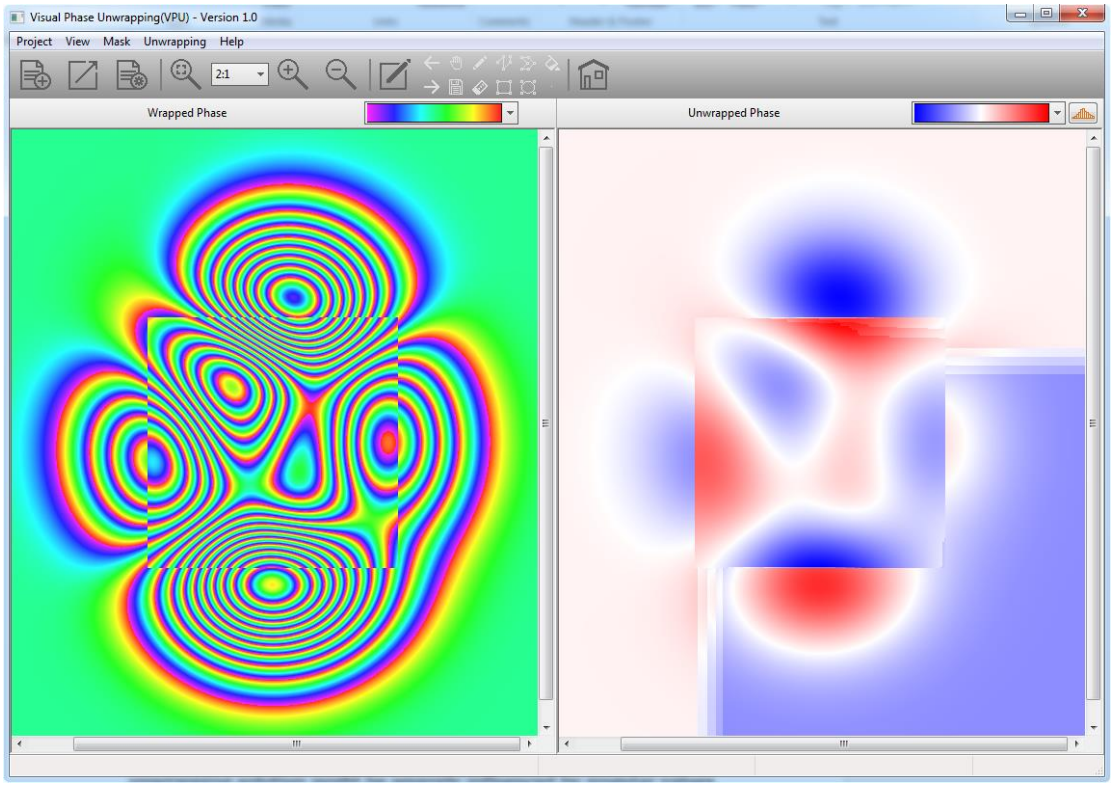


After the adjustment, the unwrapped phase view will be automatically updated.



V. Working with Mask

In real InSAR applications, the observed interferometric phase signal might be saturated (e.g. monitoring coseismic deformation field over both sides of a seismic fault, or mapping topographic elevation over steep areas). Where this is the case, an unreasonable phase unwrapping solution might be obtained, as the example shown below.



Such a problem could be avoided by introducing masks. VPU allows users to directly editing masks on both wrapped phase view and unwrapped phase view. The procedure of mask editing is simple and similar to painting operations in common used image editing softwares (e.g. the built-in MS Paint software in windows).

5.1. Mask tools

5.1.1. Enable the mask tool panel

By default, the mask tool panel is disabled, as the figure shown below. To enable it, please tick “Mask->Edit Mask” from the menu bar or click the corresponding button located in the left of the panel.

After the panel being enabled, its status will be changed.

Note

To start a phase unwrapping process, the mask tool panel has to be disabled first. To do this, please untick “Mask->Edit Mask” from the menu bar or click the corresponding button on the tool bar again.

5.1.2. Supported shapes

After the mask tool panel being enabled, users can directly “draw” masks on both wrapped phase view and unwrapped phase view. There are 5 kinds of shapes supported by VPU. They are

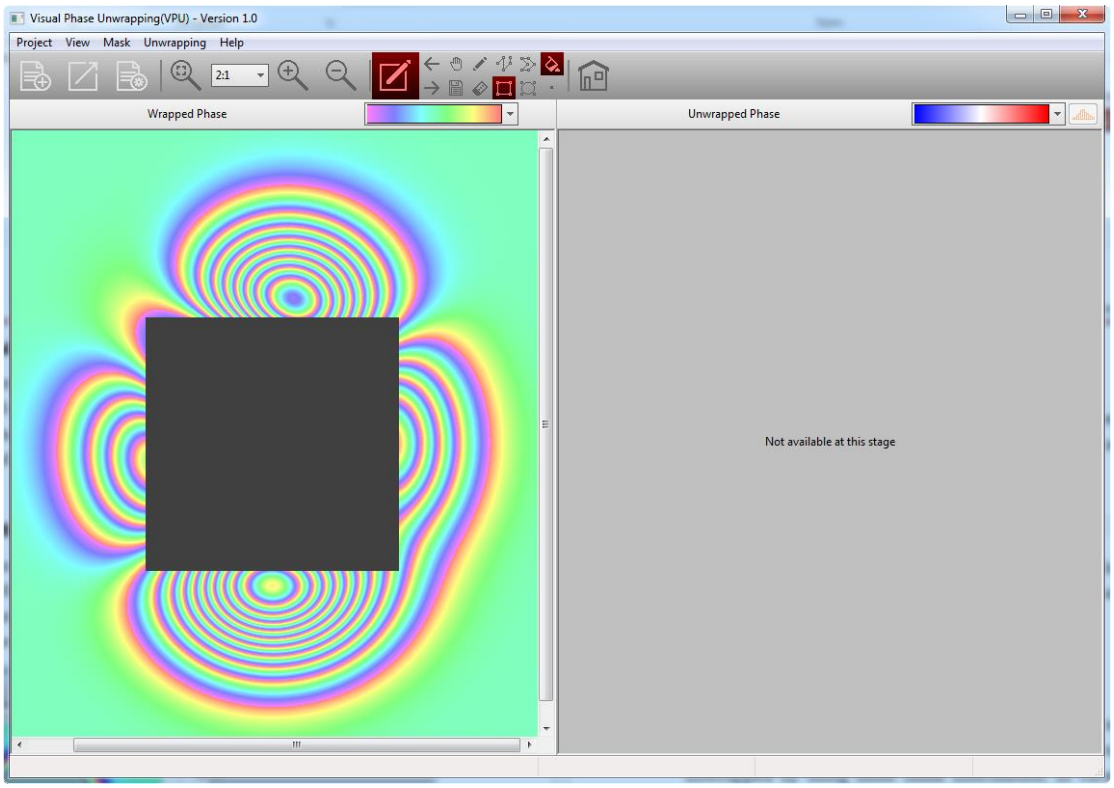
Button	Name	Description
	Pencil	Draw freeform lines by dragging the cursor
	Lines	Draw arbitrary poly-lines. It can be canceled by right-clicking the mouse.
	Polygon	Draw arbitrary polygons with three or more vertices. It can be canceled by right-clicking the mouse.
	Rectangle	Draw a square by dragging the cursor
	Ellipse	Draw an ellipse by dragging the cursor

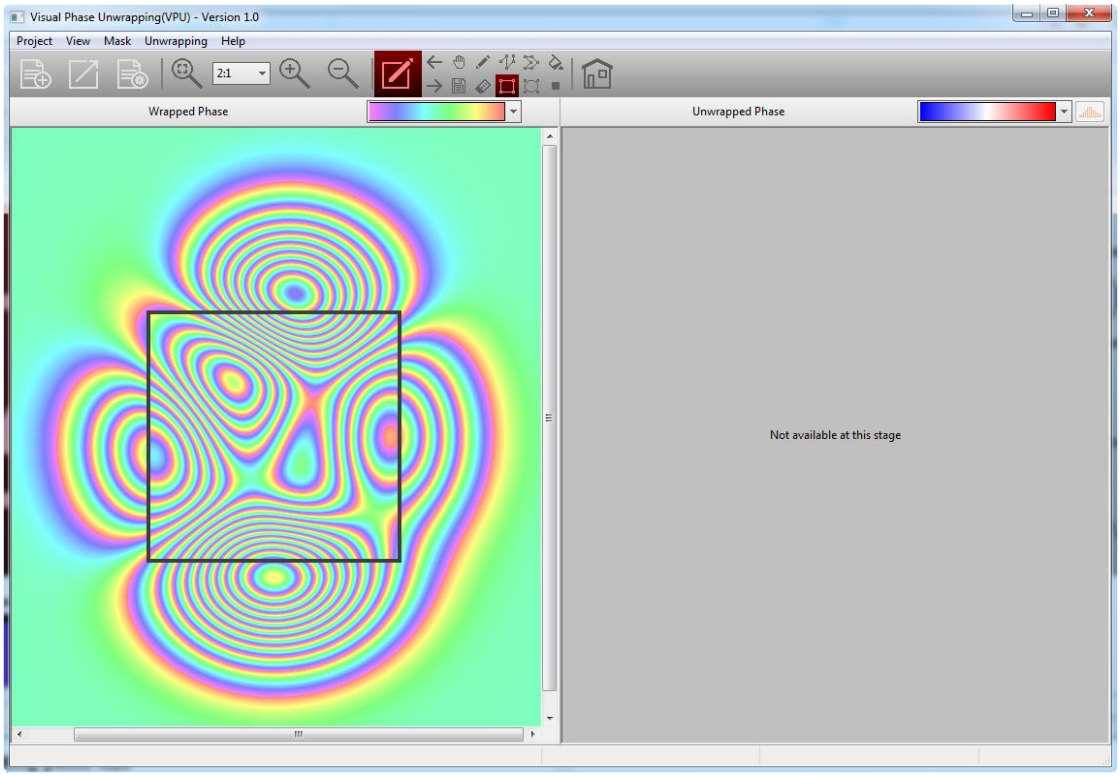
Note

VPU also provides an “eraser” tool to wipe away the excess paint. Users can enable/disable this mode by clicking the button / .

5.1.3. Enable/Disable fill

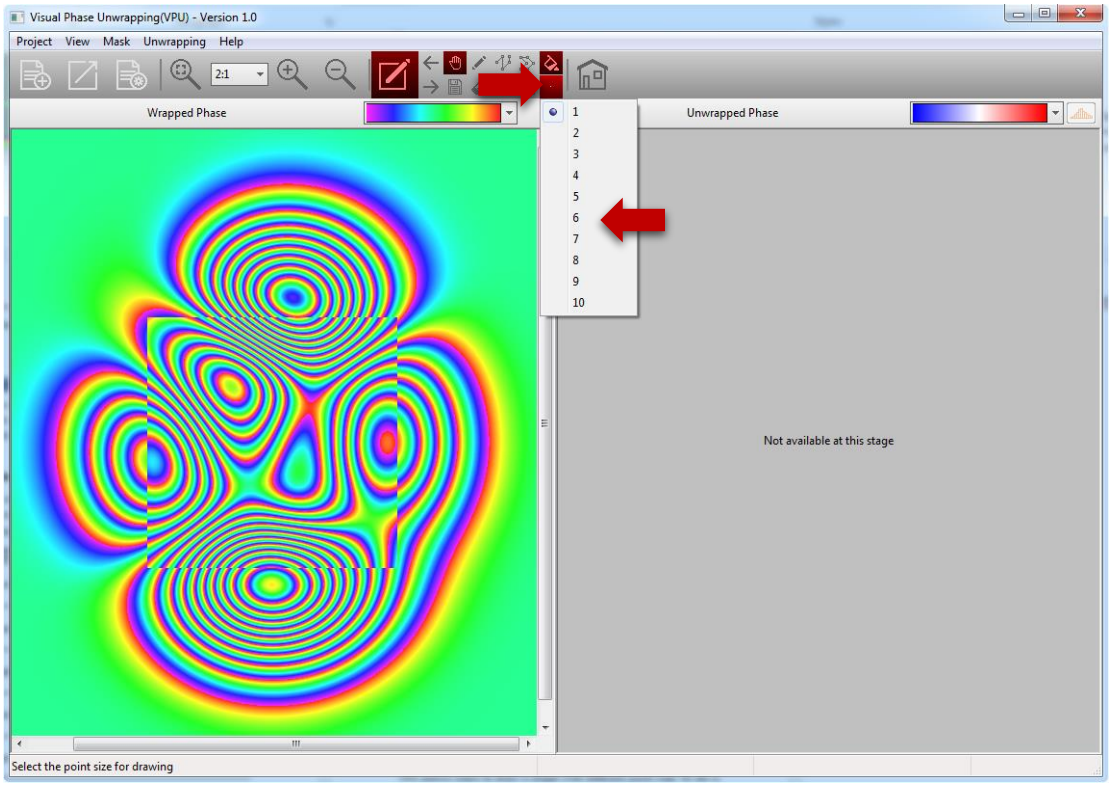
Users can enable/disable VPU to fill enclosed shapes. To do this, please click the corresponding button on the mask tool panel. The following figures present an example of filled/unfilled shape.


Visual Phase Unwrapping(VPU) - Version 1.0
Project View Mask Unwrapping Help
Wrapped Phase
Unwrapped Phase
Not available at this stage


Visual Phase Unwrapping(VPU) - Version 1.0
Project View Mask Unwrapping Help
Wrapped Phase
Unwrapped Phase
Not available at this stage

5.1.4. Selecting point size

VPU allows users to draw a shape with different point size. To set it, please click the button located on the right-bottom of the mask tool panel. A point size menu will be popped up subsequently. Users can select their preferred size from this menu, as shown below.



5.1.5. Undo/Redo mask operations

If you make a mistake editing a mask, you can undo the mistake by clicking the button ← or directly using the keyboard short cut "Ctrl+Z". Likewise, if you undid a step and then realized you should have kept that step, you can redo the step by clicking the button → or directly using the keyboard short cut "Ctrl+Y".

5.1.6. Save mask information

In VPU, the mask information will be automatically saved to hard disk when the phase unwrapped process is started. You can also save it

during the mask editing by clicking the button .

Note

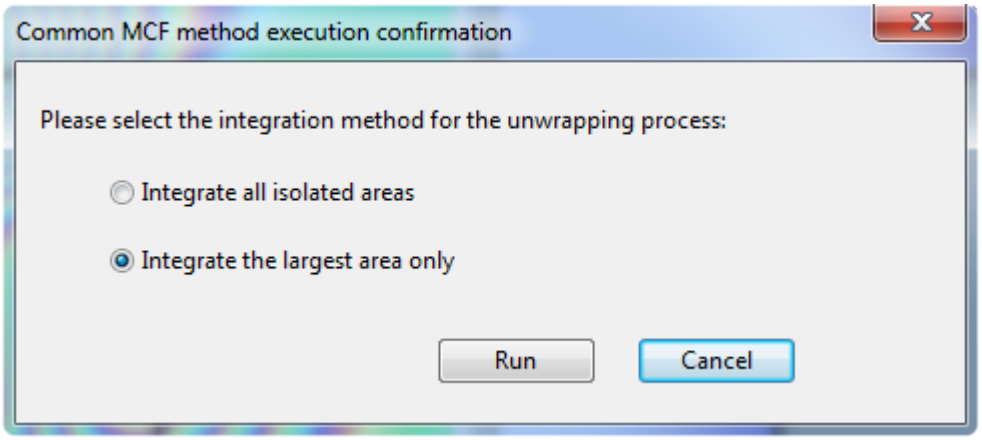
The extension of a VPU project file and its corresponding mask file is "vpu" and "vpum". The file name of stored mask information (without extension) is same as the project file.

5.1.7. Load mask from another project

In real applications, several interferograms referenced to a same master image are required to be analyzed. Users may want them to be unwrapped by using same mask information. In view of this, VPU allows users to load mask information from another VPU phase unwrapping project. To do this, please choose "Mask->Load Mask from Another Project" from the menu bar.

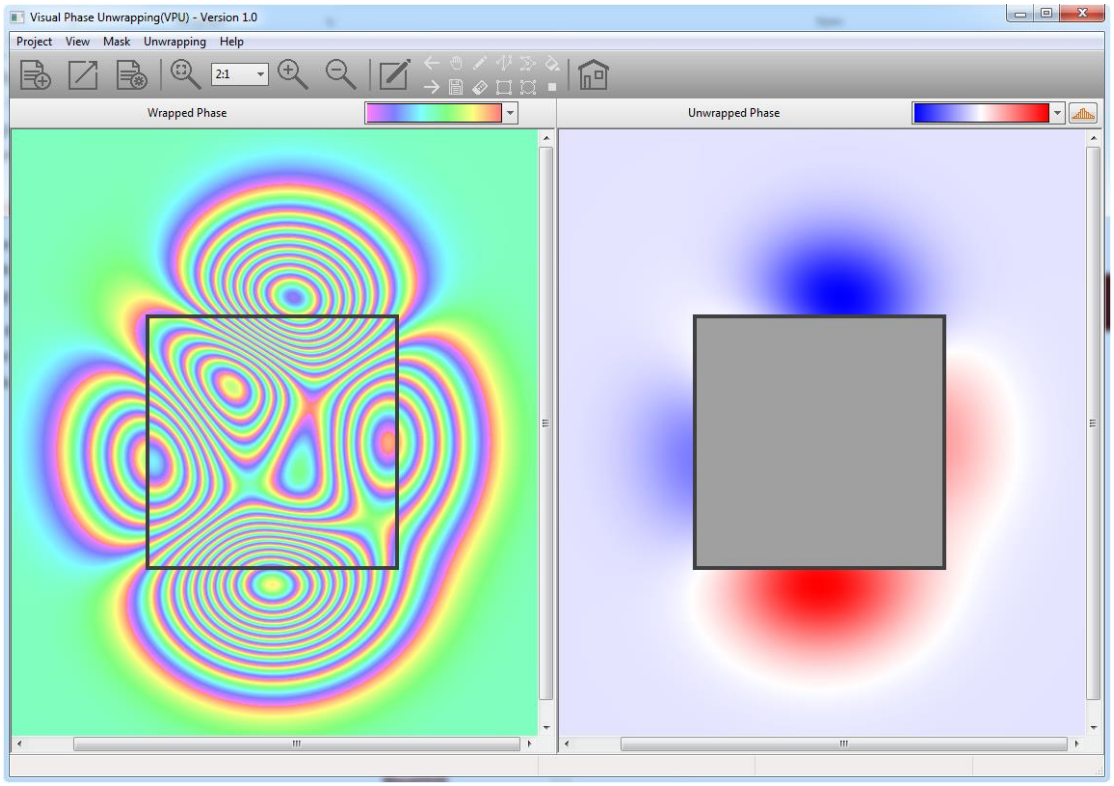
5.2. Integration method selection

Due to the presence of mask, an interferogram might be separated into several isolated areas. VPU will ask users to select an integration method before a phase unwrapping process.

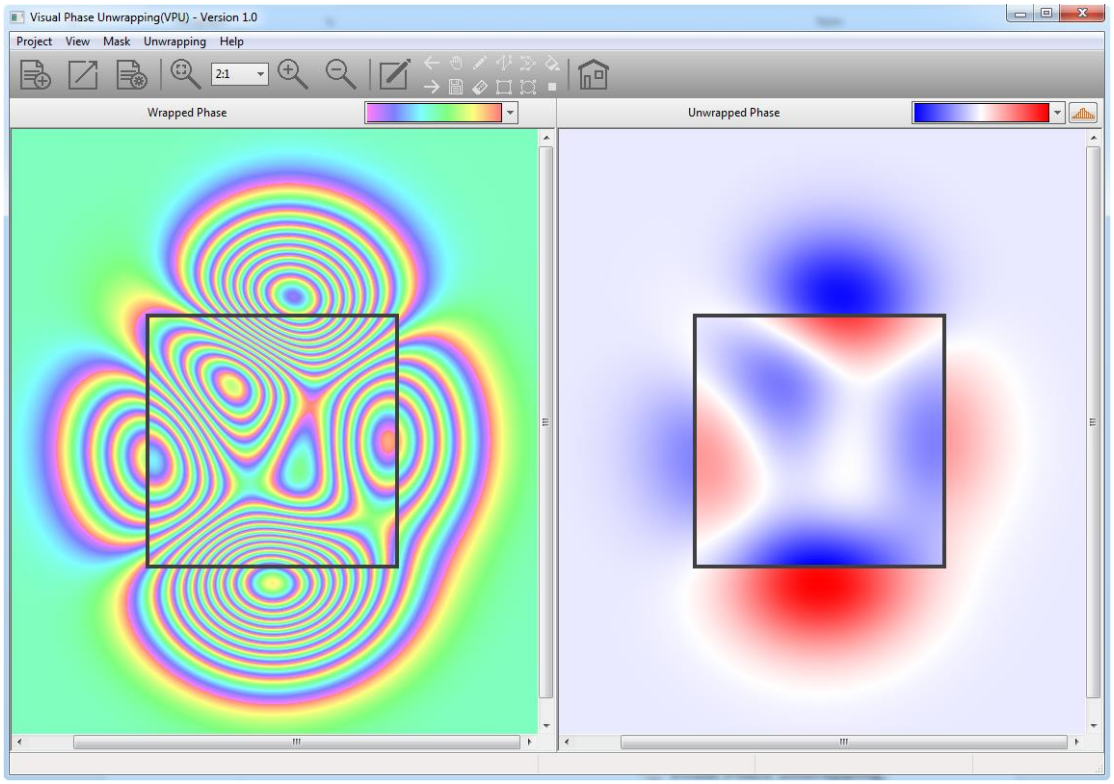

Common MCF method execution confirmation
Please select the integration method for the unwrapping process:
Integrate all isolated areas
Integrate the largest area only
Run
Cancel

There are two integration methods in VPU. They are

- **Integrate the largest areas only:** If this method is selected, the phase unwrapping result will only contain the largest area, as the example shown below.



- **Integrate all isolated areas:** If this method is selected, the unwrapped phase of each isolated area will be included in the final result. *Note that the result of each area is independent to each other*.



VI. Working with Cost

6.1. Cost rescaling

As mentioned previously, VPU supports four data formats (Int16, Int32, Float and Double) for input cost files. However, for the purpose of improving calculation efficiency, VPU will rescale every cost value to an integer between 1 and 20.

6.2. Suggestion

If unsuitable cost information is used in a MCF phase unwrapping process, the accuracy of the resulting unwrapped phase might be severely decreased. If the cost data is not set, VPU will apply an equal cost plan to the MCF network. In most cases, this plan can meet the requirement of a phase unwrapping application. It would better not to use cost if you are not familiar with the principle of phase unwrapping.

VII. REFERENCES

[1]wxWidgets home website: http://www.wxwidgets.org.

[2]M. Costantini., "A novel phase unwrapping method based on network programming", IEEE Transactions on Geoscience and Remote Sensing, vol.36, no.3, pp.813–821, May 1998.

[3]K. Zhang, L. Ge, Z. Hu, A.H. Ng, X. Li, and C. Rizos, "Phase Unwrapping for Very Large Interferometric Data Sets", IEEE Transactions on Geoscience and Remote Sensing, vol.49, no.10, pp.4048–4061, October 2011.

[4]LEMMON home website: http://lemon.cs.elte.hu/trac/lemon.